The BTeV Ring Imaging Cherenkov Detector

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BTeV/Co

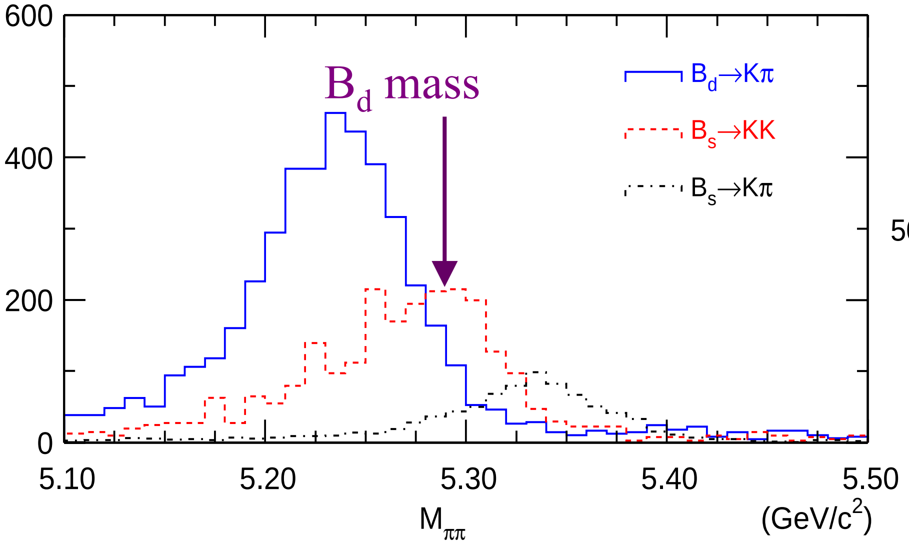
Some of the crucial measurements

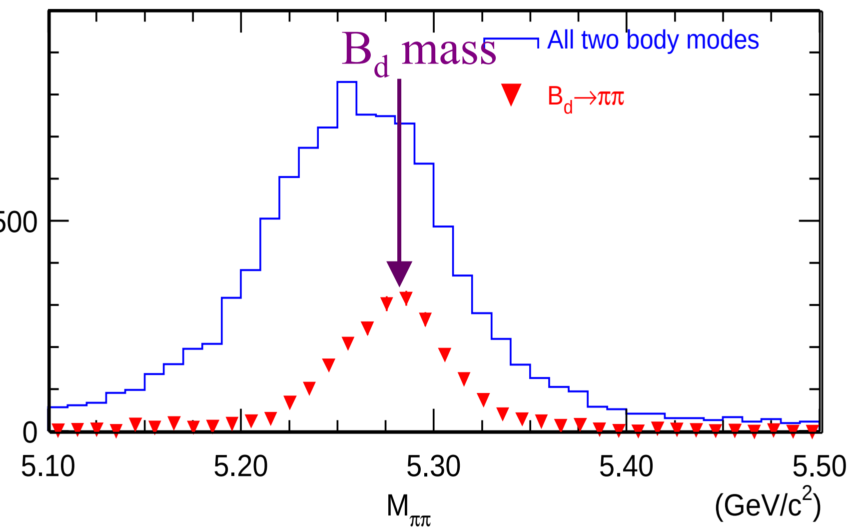
RICH

Physics Quantity	Decay Mode	Vertex Trigger	K/π sep	γ det	Decay time σ
$\sin(2\alpha)$	$B^o \to \rho\pi \to \pi^+\pi^-\pi^o$	✓	✓	✓	
$\sin(2\alpha)$	$B^o \to \pi^+\pi^-$ & $B_s \to K^+K^-$	✓	✓		✓
$\cos(2\alpha)$	$B^o \to \rho\pi \to \pi^+\pi^-\pi^o$	✓	✓	✓	
$\mathrm{sign}(\sin(2\alpha))$	$B^o \to \rho\pi$ & $B^o \to \pi^+\pi^-$	✓	✓	✓	
$\sin(\gamma)$	$B_s \to D_s K^-$	✓	✓		✓
$\sin(\gamma)$	$B^o \to D^o K^-$	✓	✓		
$\sin(\gamma)$	$B \to K \pi$	✓	✓	✓	
$\sin(2\chi)$	$B_s \to J/\psi\eta'$, $J/\psi\eta$		✓	✓	✓
$\sin(2\beta)$	$B^o \to J/\psi K_s$				
$\cos(2\beta)$	$B^o \to J/\psi K^*$ & $B_s \to J/\psi\phi$		✓		
x_s	$B_s \to D_s\pi^-$	✓	✓		✓
$\Delta\Gamma$ for B_s	$B_s \to J/\psi\eta'$, K^+K^-, $D_s\pi^-$	✓	✓	✓	✓

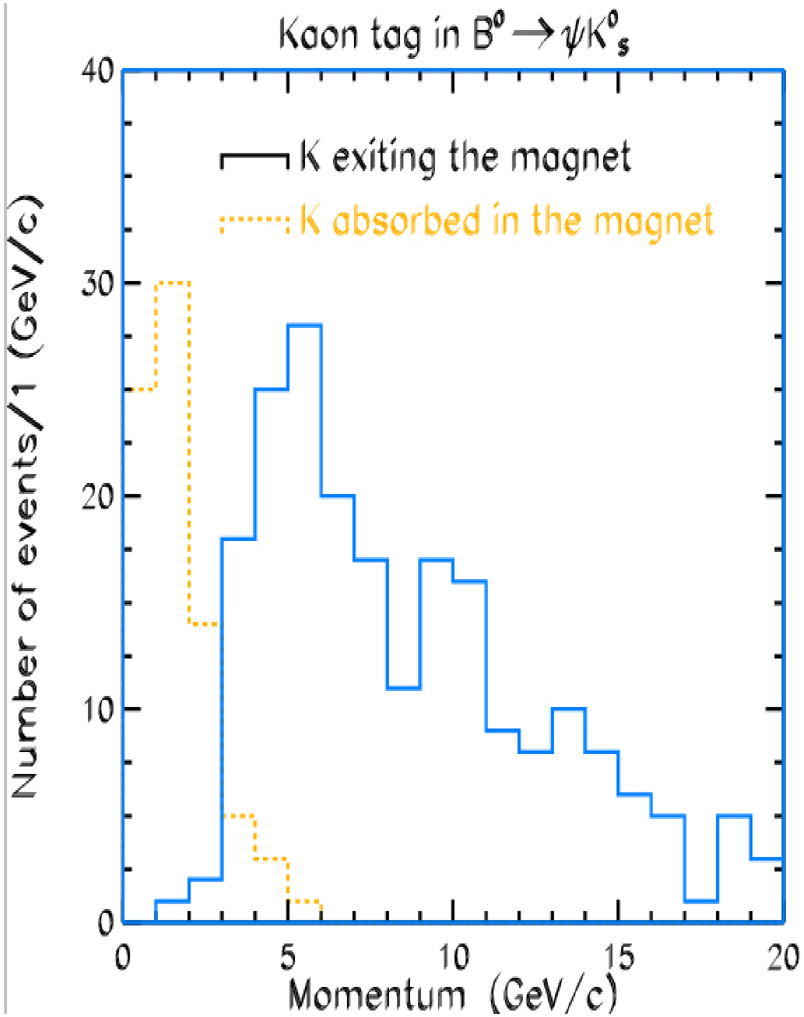
Requirements on p_{max}: $B^o \to \pi^+ \pi^-$,

- a clear example of the importance of K/π id
- We require that each π be properly identified in the RICH. Otherwise the measurement is probably impossible.
- This mode determines the p_{max} in our momentum range requirements



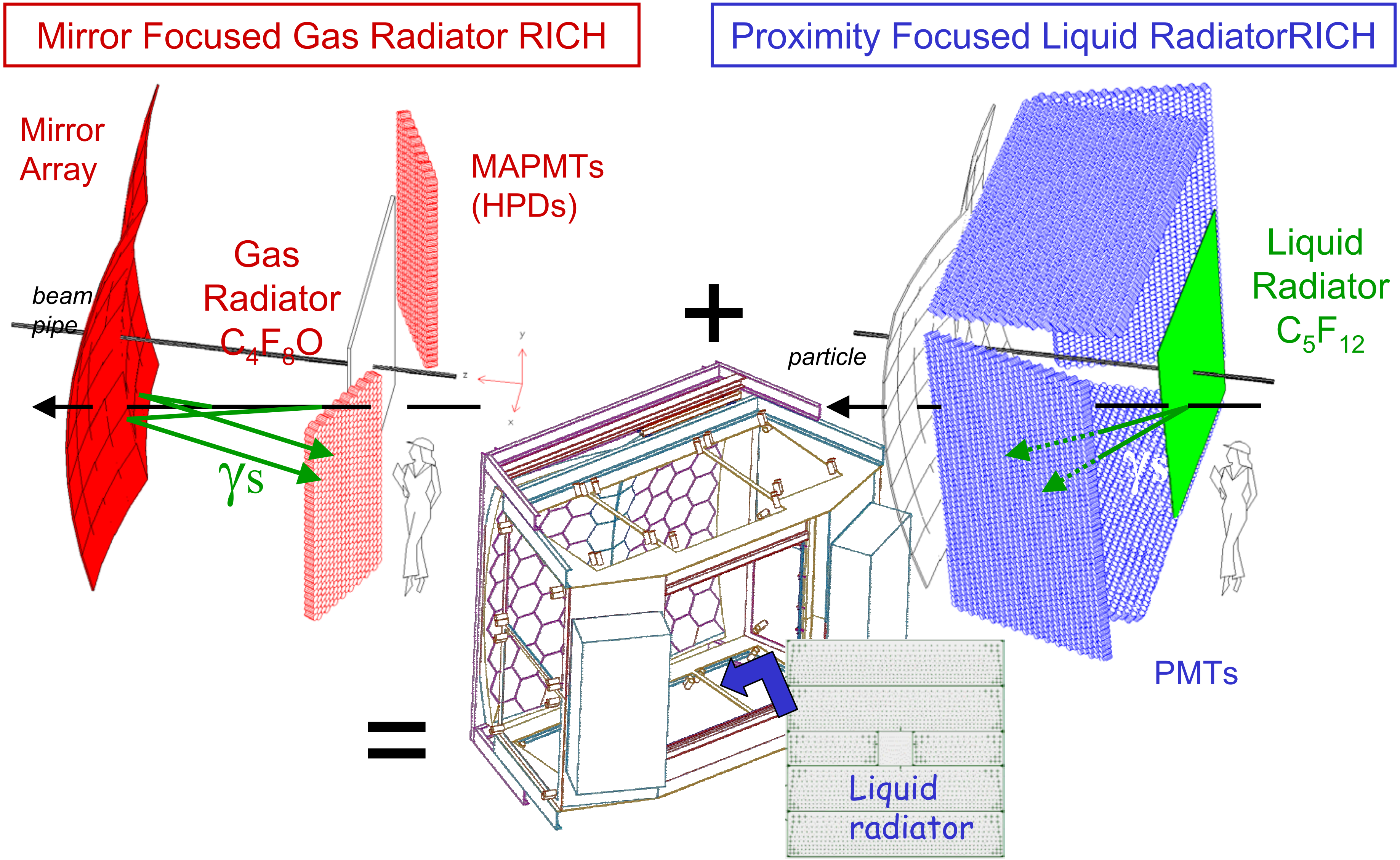


Requirements on p_{min}: optimum tagging efficiency



- The π/K/p separation is crucial to optimal flavor tagging efficiency
- Our 2-radiator system gives optimum efficiency and p/K/π separation in the whole momentum range of interest
- The RICH detector will also extend the lepton identification at low momenta beyond the aperture of the calorimeter and muon system$\Rightarrow$ much better lepton efficiency, enhanced flavor tagging…

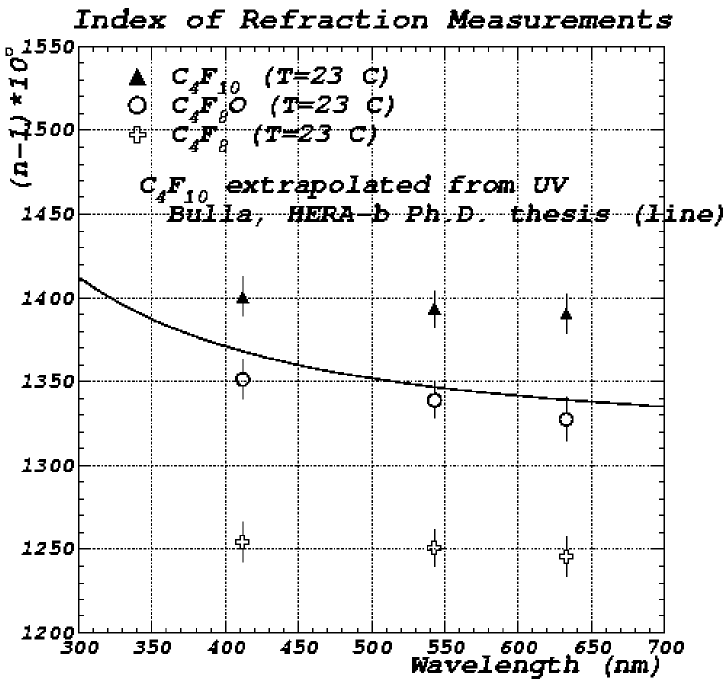
The BTeV RICH Components

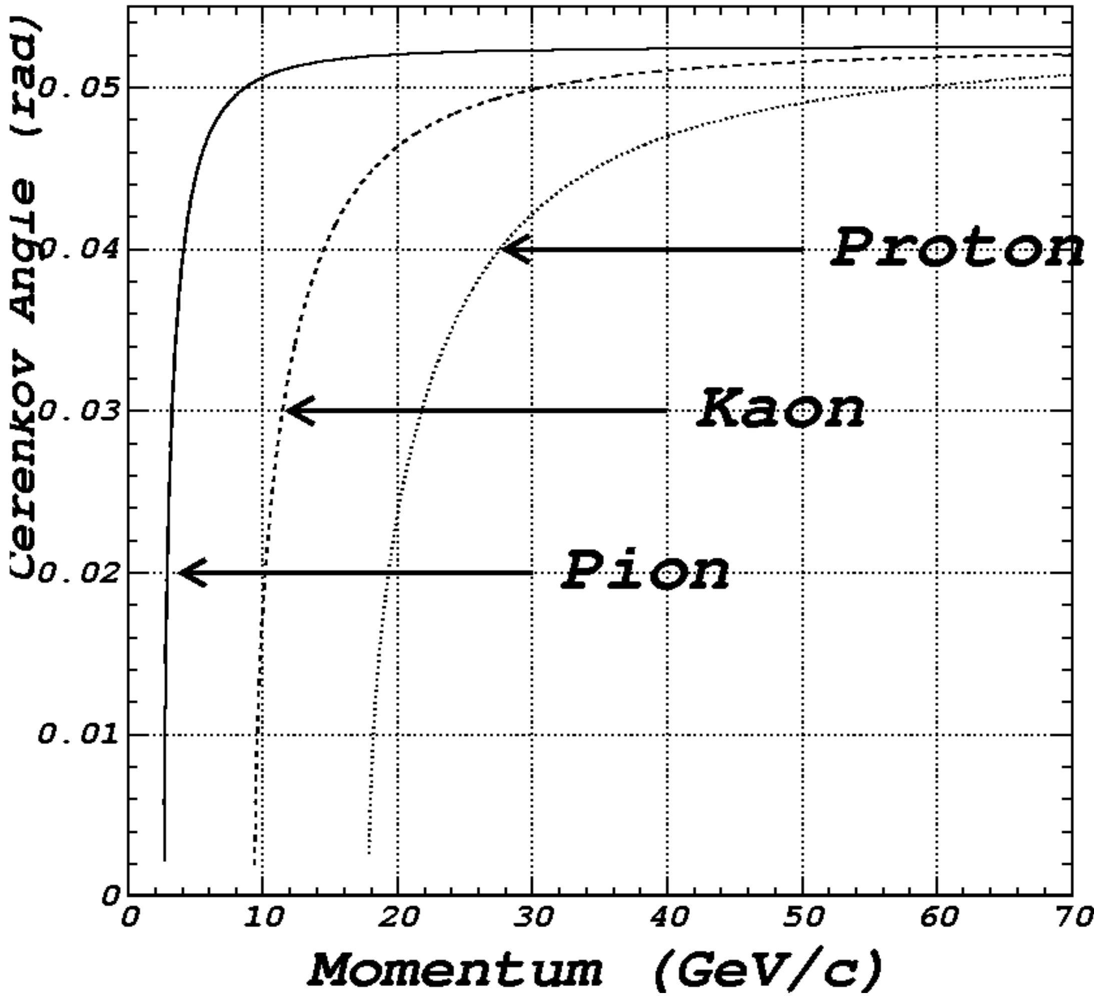


Gas Radiator+ MAPMTs: focused RICH

Gas: C_4F_8O

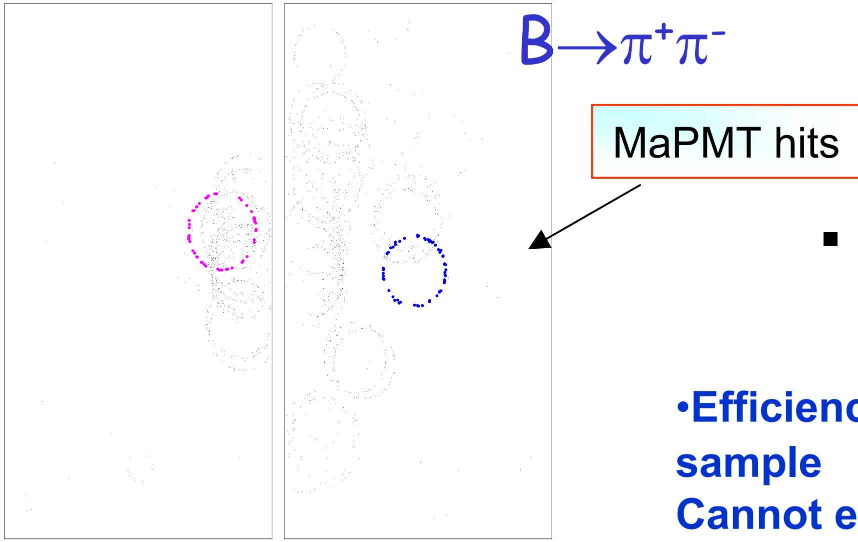
* K/π separation for
  3 < p <70 GeV
* P/K separation for
  9.5 < p < 70 GeV





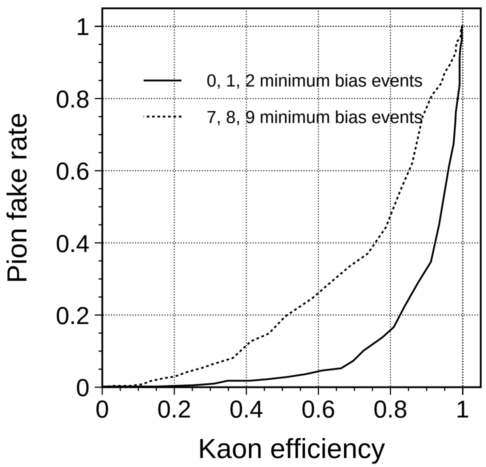
No p/K separation below ~ 9.5 GeV with gas alone

Illustration of the physics impact of gas radiator



- Based on a full Geant simulation

•Efficiency versus fake rate for a $B_s \to D_s K$ sample
Cannot extract γ from $B_S \to D_s K^-$ without suppression of $B_S \to D_s \pi^-$

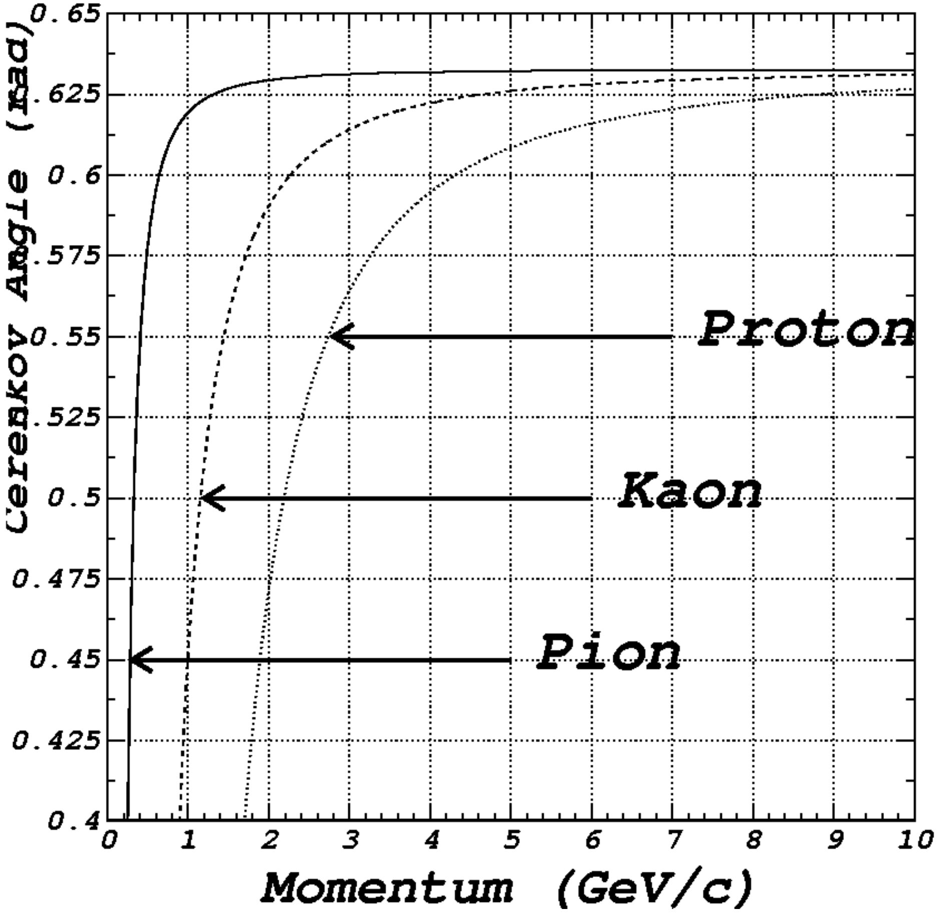


Liquid Radiator+PMT:proximity focused RICH

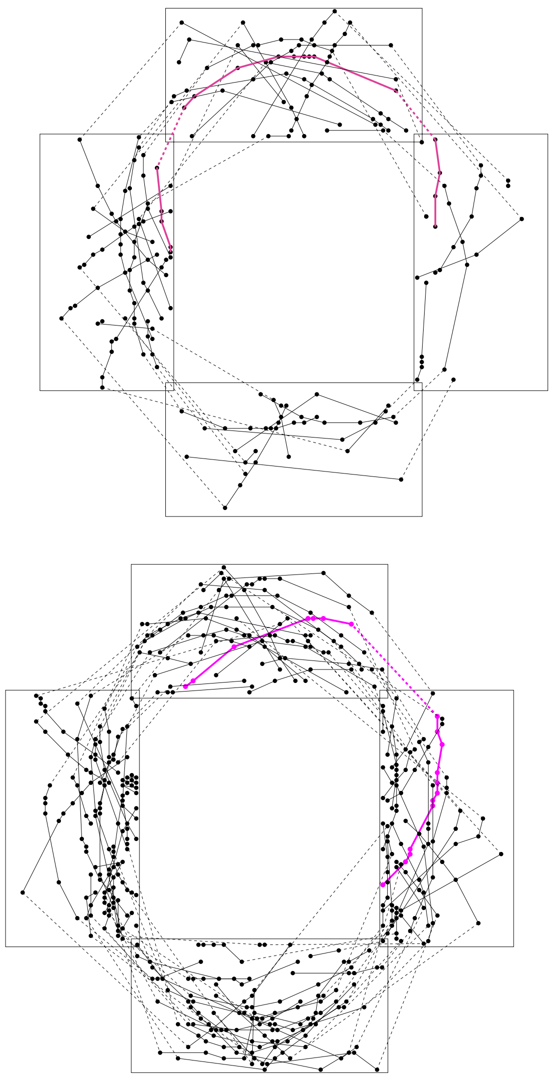
C_5F_{12} (n=1.24):

-Extends p/K separation to p<9.5 GeV

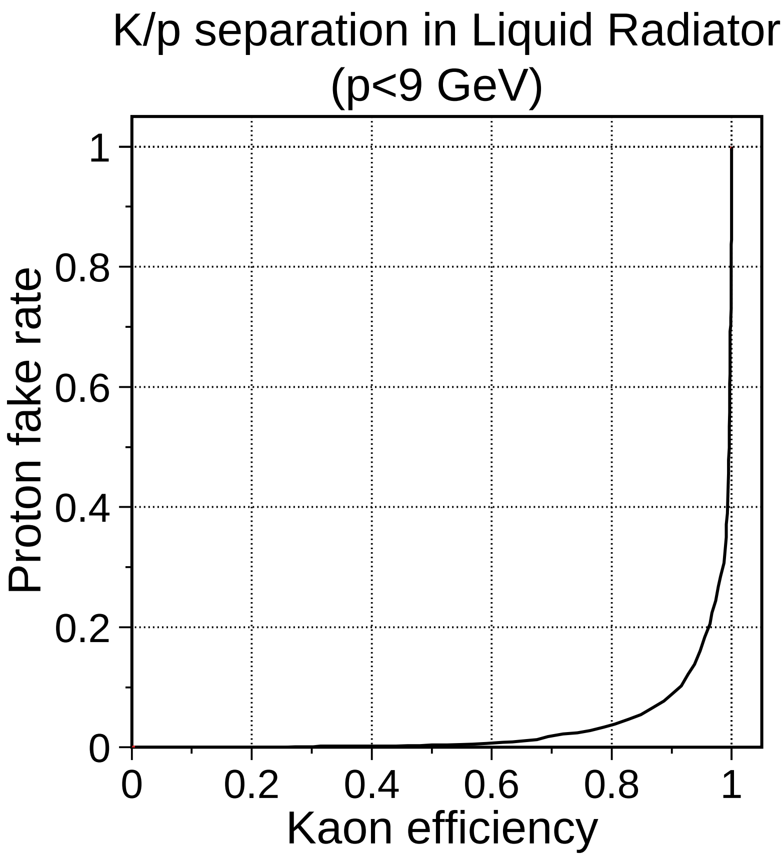
-Extends K/π separation into the p<3 GeV range



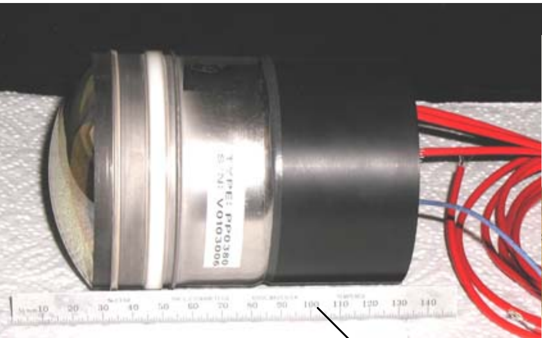
Physics performance of liquid radiator

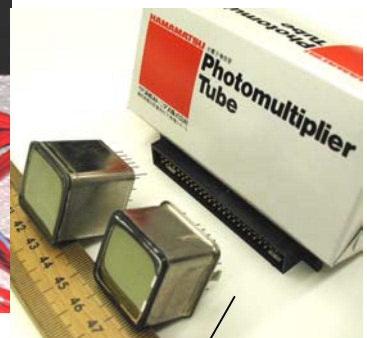


- Main goal: improving K tagging efficiency:
  - 10-20% improvement with respect to gas radiator only



Gas RICH Photon Detector Options





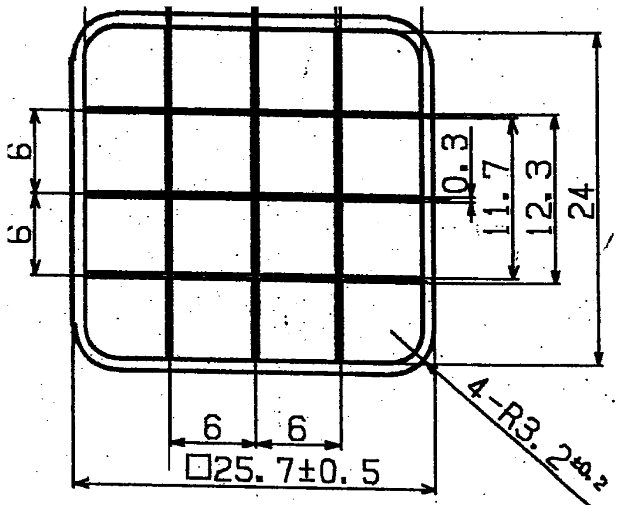
System	HPD	MAPMT
Number of tubes	944	9016
Cost per tube	$6353	$529
Photodetector cost	5,997 k$	4,769 k$

System	HPD	MAPMT
Effective pixel size	5.5 mm hex	6 mm square
QE*CE*Geom.Eff. ? ↦ beam tests needed	0.23*0.95*0.623 =0.136 ?	0.26*0.7*0.79 =0.144 ?
HV	-20kV and -19.9kV and -15.8kV and -0.05 kV	-0.9 kV
Current draw	no	yes
Gain	5×10^3	10^6
Magnetic field sensitivity	large	R8900 – OK shielded

- Both systems satisfy our physics requirements
- Cost and system issues favor the MAPMTs →MAPMTs are our baseline photon detector

Baseline Photon Detectors: Hamamatsu MAPMT

R8900-M16 optimal size of the active area

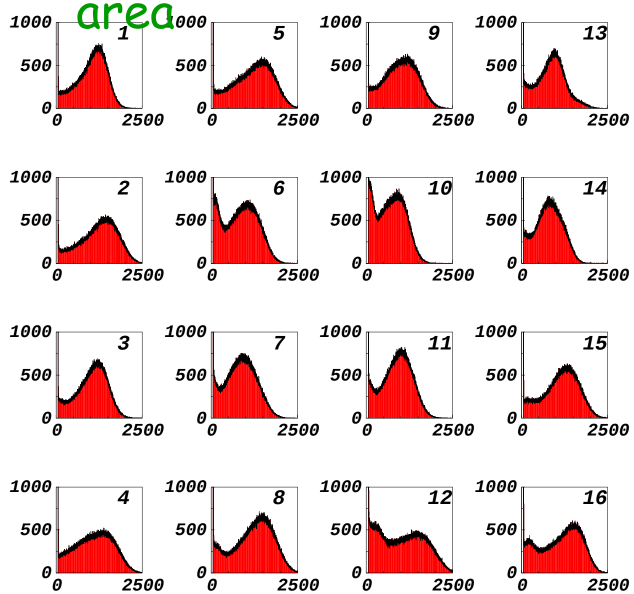


- New R8900-M16 MAPMT tube:
  - redesigned focusing scheme on the first dynode
  - Active area is 85%

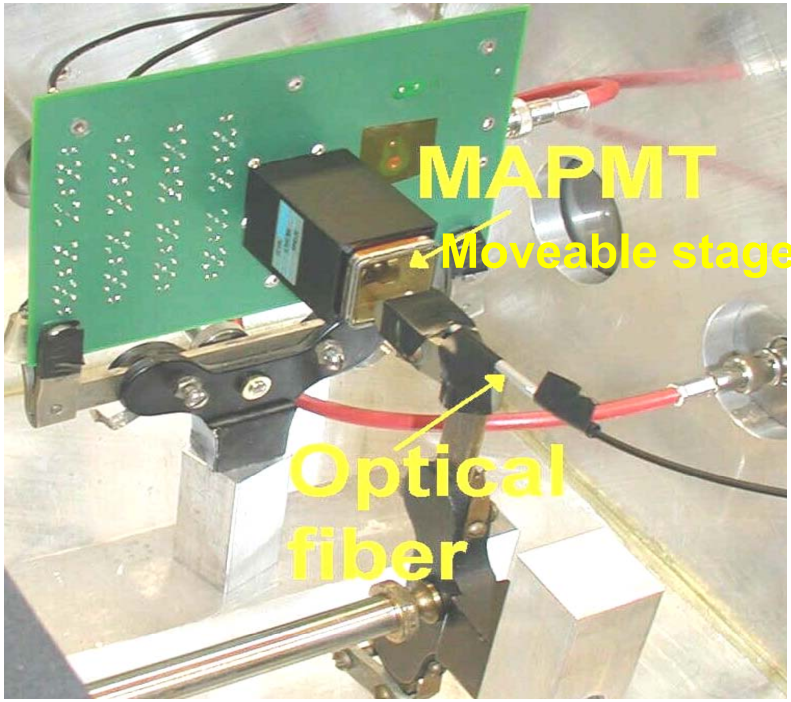
MAPMT Performance Characterization

We have acquired 2+ 52 MAPMTs: 2 Fully characterized & 52 recently purchased for upcoming test beam studies.

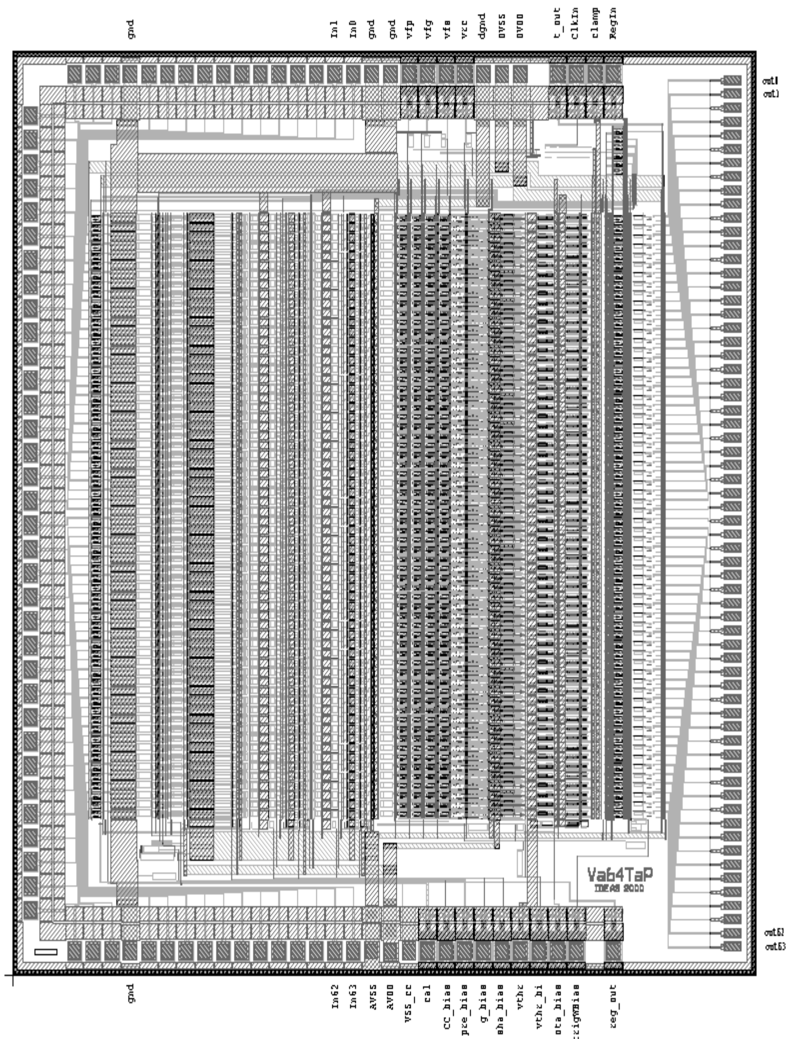
- Characterization steps:
  - Plateau
  - Active area
  - Gain and collection efficiency (CE) variation over the tube area



PULSE HEIGHT DISTRIBUTIONS FOR THE 16 CHANNELS OF R8900-M16 PROTOTYPE



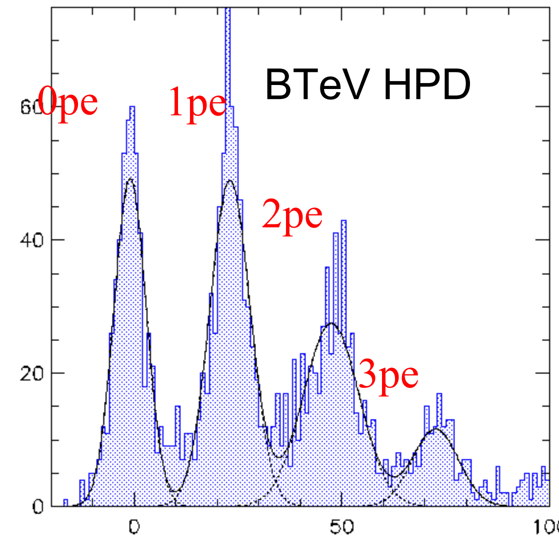
Photon detector electronics

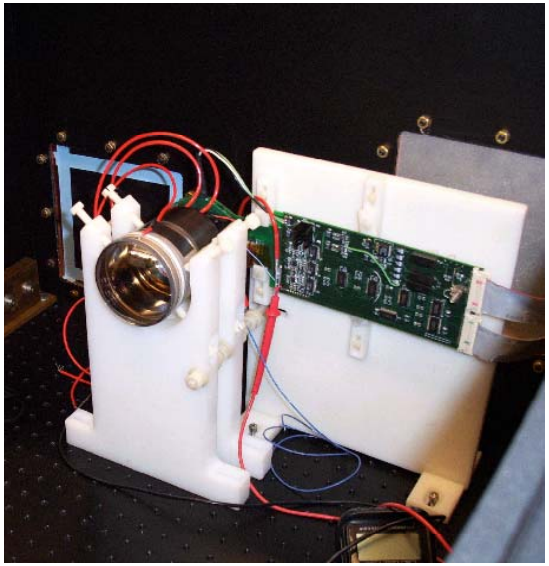


- FRONT END ASIC must
  - Low noise (~1000 e^-)
  - On chip sparsification
  - High Dynamic range
  - Parallel digital readout to allow event synchronization
- PROTOTYPING STEPS implemented:
  - VA_BTeV1 [for HPD readout: low noise (500e^- ENC), discriminator not optimized for high counting rates]
  - VA_MaPMT [for MAPMT, improved discriminator, 1 analog test channel]
  - Va+BTeV1.1 [improved discriminator and 1 analog test channel]

BTeV HPD

- 15 prototypes tested at Syracuse with LED light using CLEO III VA-RICH readout:
  - HPD works as expected
  - The development was a success!
- HPD being tested with VA_BTeV front end electronics
  - Seen response to single photoelectron
  - A system of 15 fully instrumented HPD's is being assembeld and will be studied in a test beam at FNAL in June 2004

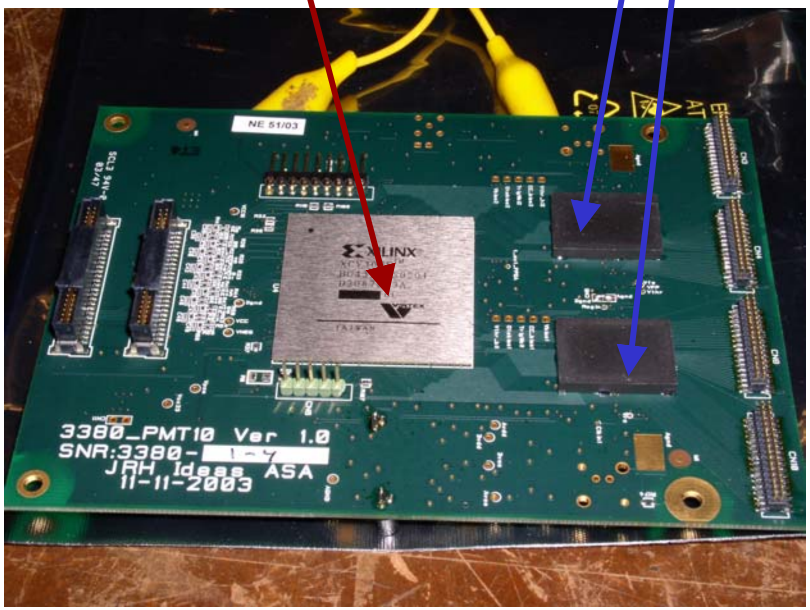




The MaPMT Hybrids

FPGA for data flow control

2 ASICs under light shield-caps

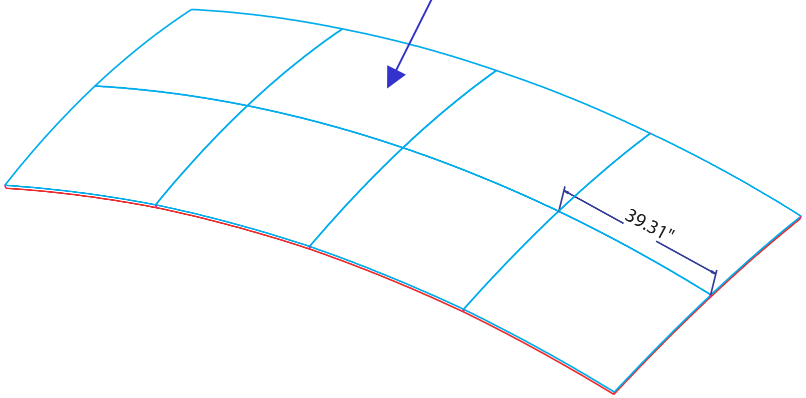


- 2 ASIC [128 channels] hybrids designed to process the information of 8 MaPMTs.
- Preliminary tests show that they match our requirements.
- 15 hybrids have been produced for MAPMT system for the June 2004 test beam run.

The RICH Mirror System

- Two large mirrors, each one has 200cm (width) and 400cm (height). They can be broken down to any number of mirrors of any shape, so that cost and performance are optimized.
- A half circle hole in the side (of radius ~3 cm).
- Mean radius is fixed to 697cm.
- 1-2% radiation length
- CMA approach: each mirror made up of 8 square tiles

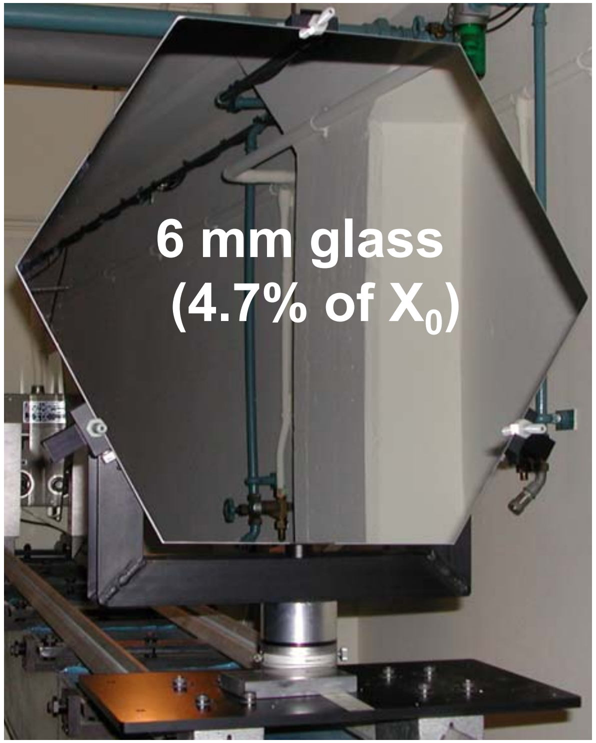
½ of RICH mirror based on CMA segment design

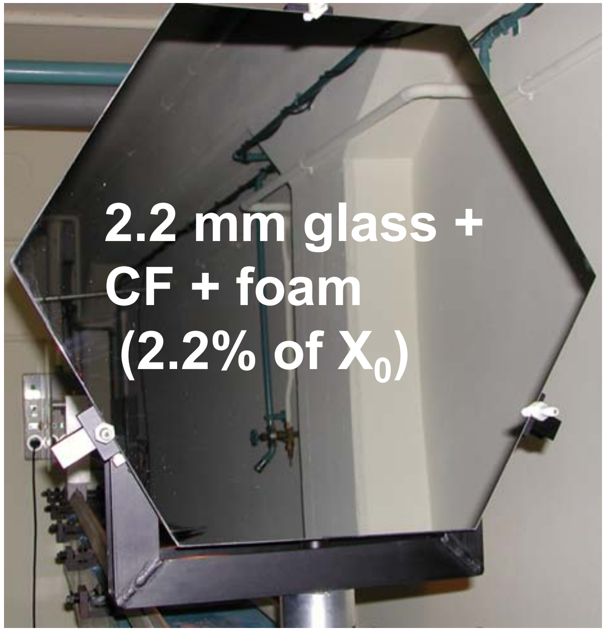


Example of CMA PROJECTS

•CMA provided competitive quote & demonstrated capabilities beyond our needs (optical properties controlled to fraction of a wave)

Mirror R&D





Turnov, Czech Republic (COMPAS)
About the right size and curvature. Good quality.
We will use them in the 2004 test beam.

- Visited mirror manufacturing companies
- Assembled mirror QA test station
- Extensive simulation to determine mirror requirements

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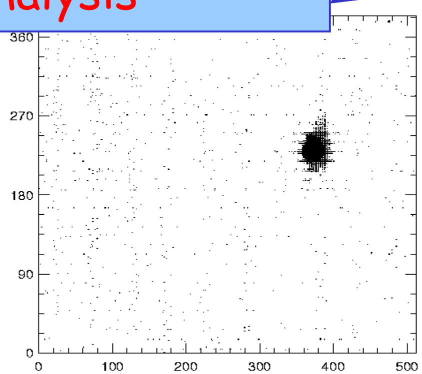
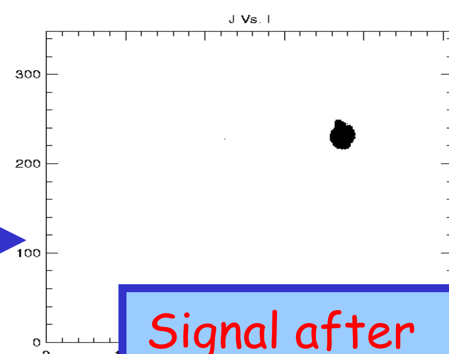
Mirror spot size characterization at Syracuse

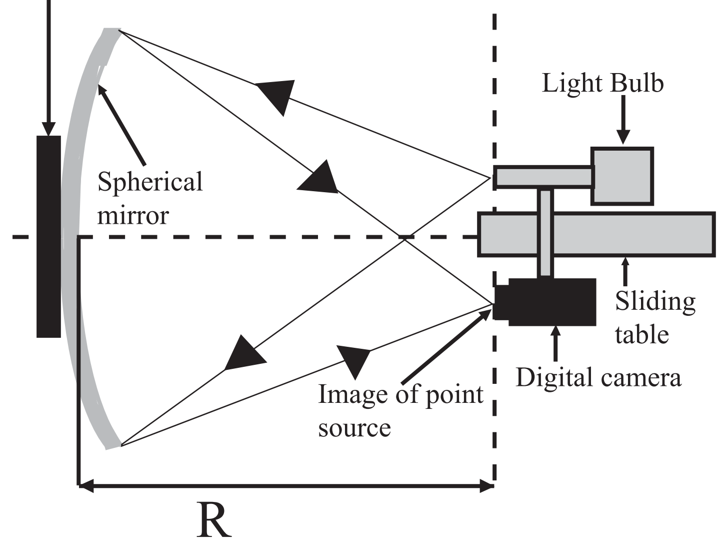
Glass mirror spot image

Image digitized for quantitative analysis





Signal after pedestal subtraction

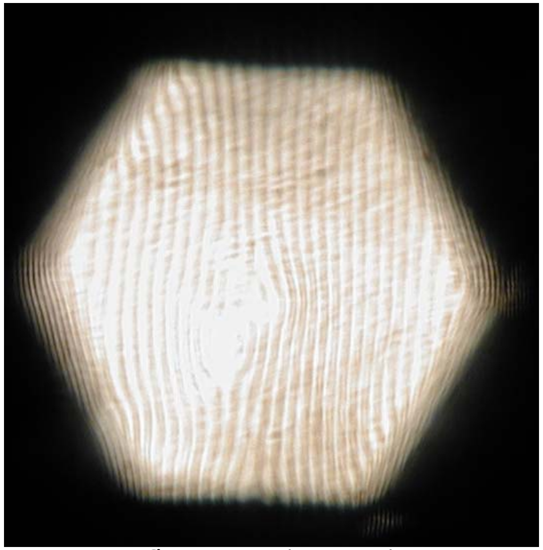


Mirror	D_{95}(mm)	R_{mean} (cm)
Glass	2.97	659
CF	4.10	648

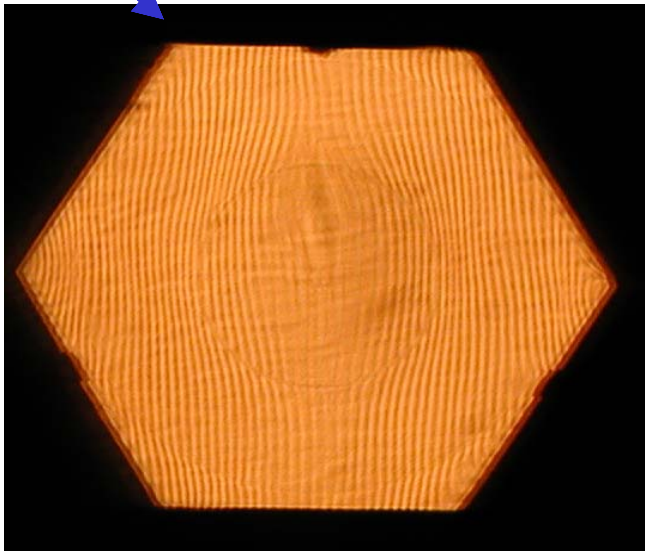
Ronchi patterns of test beam mirrors

•Point source located at the center of curvature of the mirror

•Glass mirror shows zonal features (concentric rings) presumably associated with the grinding and polishing of the mirror



Composite mirror

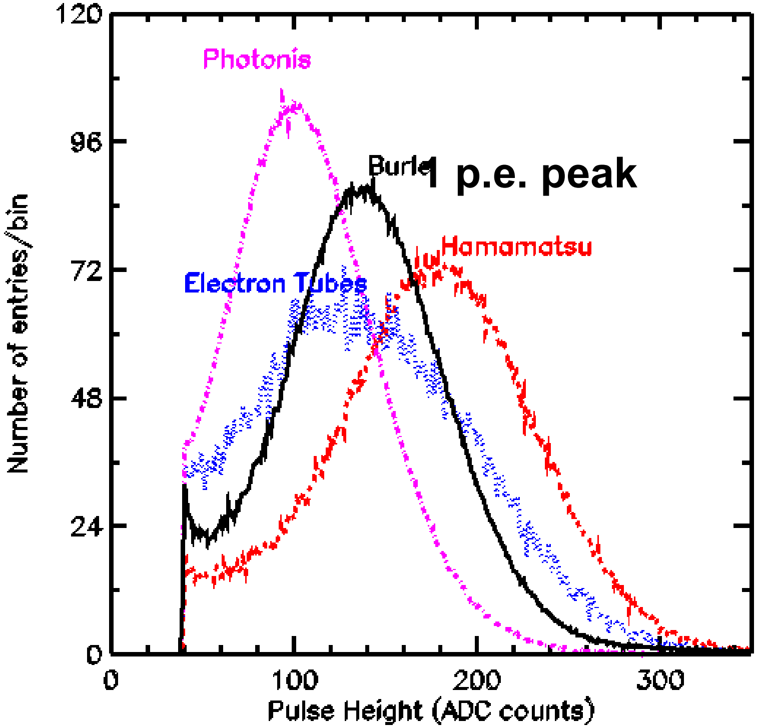


Glass mirror

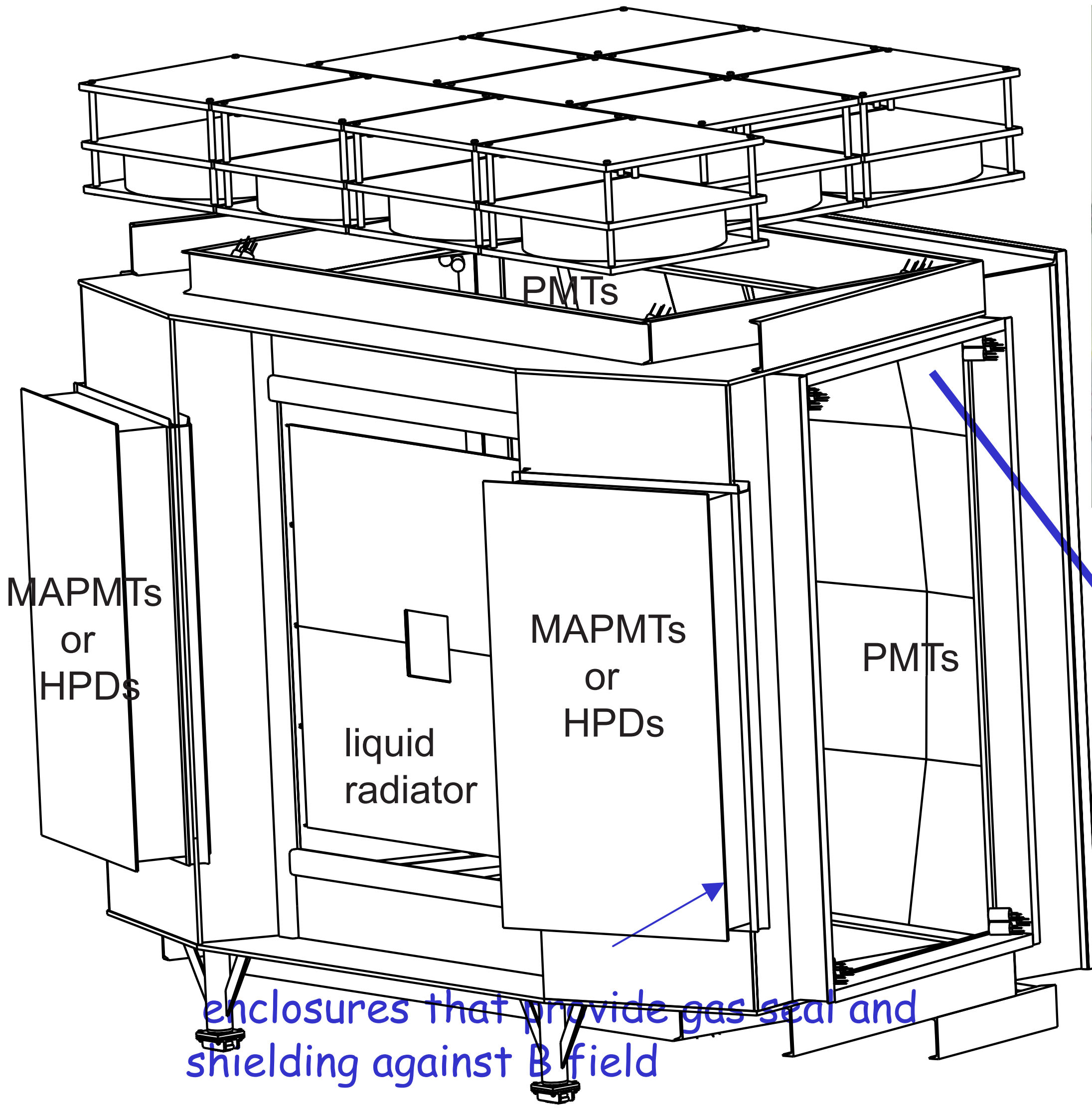
Gratings 50 lines/inch

Photodetectors for the Liquid Radiator RICH

- Standard (single anode) 3" PMT:
  - Need about 5,000 tubes
  - 8-stage box dynode structure; gain ~10^5
  - Produced in mass quantities for medical applications
- We tested sample tubes from 4 manufacturers:
  - Burle, Electron Tubes, Photonics and Hamamatsu
  - All capable of detecting a single photon
  - Magnetic field sensitivity was determined (OK when shielded by mumetal tubes)

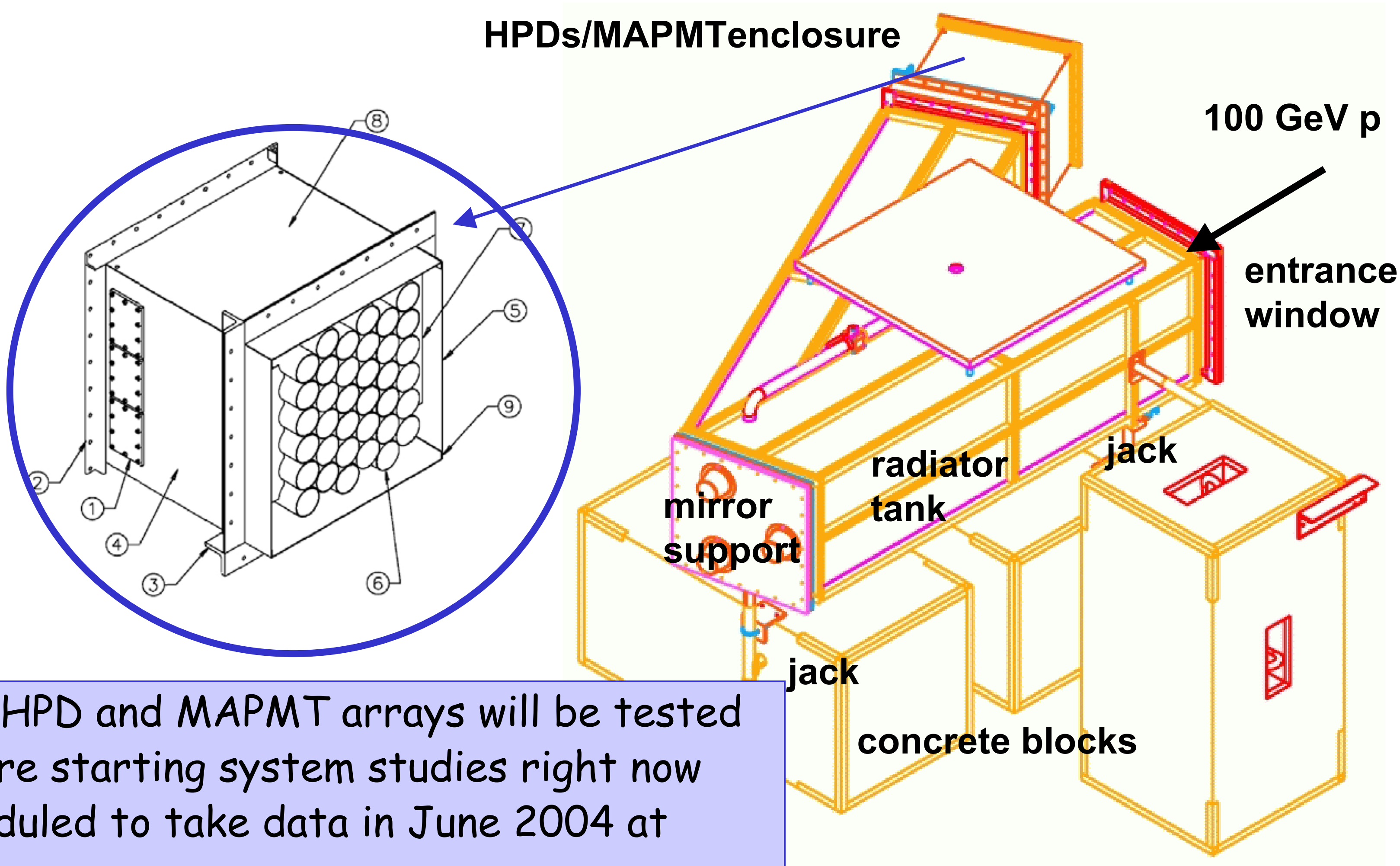


RICH Mechanical design



Mirror mount and support panel prototype

The Gas RICH Test Beam Prototype



- Both HPD and MAPMT arrays will be tested
- We are starting system studies right now
- Scheduled to take data in June 2004 at FNAL

Construction Cost

	Base	Contingency(%)	Total
M&S	9.91 M$	38	13.66M$
Labor	2.17 M$	27	2.77 M$
Total	12.08M$	36	16.43M$

- Fully loaded
- In FY05 $

Participants and Expertise

Syracuse HEP group

CLEO III RICH at Syracuse

BTeV RICH Level 2 Managers at work on CLEO III RICH

Other major contributions to the construction projects (as individuals):

- FRAM at CERN (M.Artuso)
- CDF SVX II (S.Blusk)
- D0 Silicon and Fiber Tracker (H. Cease, FNAL)
- Various RICH R&D with Ypsilantis & Seguinot (R. Mountain)
- CLEO-II Muon Detector (T.Skwarnicki)
- CLEO-II CsI(Tl) EM Cal (S.Stone)
- CLEO-I dE/dx Chambers (S.Stone)

The existing team is large enough to handle it all, but new collaborators will be more than welcome

BTeV/C0

Conclusions

- Dual radiator RICH (mirror focused gas radiator + proximity focused liquid radiator) will provide excellent hadron identification and enhance lepton identification
- Prototypes for all the subsystems developed and studied in test stands at Syracuse
- Extensive test beam studies of gas RICH with both photon detector options in June 2004
- Cost in check via multiple vendors/technologies
- Experienced team that has already built a large RICH system (CLEO RICH, operating extremely well since 1999 at CESR e^+e^- collider)